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Compiled by	Approved by	Authorized by
Sibongile Maphosa	Sibongile Maphosa	Bheki Ntshangase
Engineer	Engineer	Senior Manager TX AME – SE&D
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Supported by SCOT/SC

Bheki Ntshangase

SCOT/SC Chairperson

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1. Introduction

This standard stipulates Eskom's requirements for designing, manufacturing and testing of inductive voltage transformers up to 132kV. The requirements stipulated in this document are based on international practices combined with Eskom's experiences. The requirements are specified in order to ensure the integrity of the product thereby minimising the risk of failure of equipment.

2. Supporting clauses

2.1 Scope

This standard details the requirements applicable to inductive voltage transformers used in Eskom for nominal voltages up to 132kV used for measurements and protection purposes.

2.1.1 Purpose

The document is written to capture and standardise Eskom inductive voltage transformer requirements.

2.1.2 Applicability

This document shall apply throughout Eskom Holdings Limited Divisions.

2.2 Normative/informative references

Parties using this document shall apply the most recent edition of the documents listed in the following paragraphs.

2.2.1 Normative

[1] BS 1872 - Specification for Electroplated Coatings of Tin

[2] Eskom 240-7565504: Corrosion protection standard for new indoor and outdoor Eskom equipment, components, materials and structures manufactured from steel standard.

[3] IEC 60060-1: High voltage test techniques – Part 1: General definitions and test requirements

[4] IEC 60071-1: Insulation co-ordination – Part 1: Definitions, principles and rules

[5] IEC 60085: Electrical insulation – Thermal classification

[6] IEC 60269-2: low-voltage fuses – Part 2: Supplementary requirements for fuses for use by authorized persons (fuses mainly for industrial application) – Examples of standardized systems of fuses A to K

[7] IEC 60270: High voltage test techniques – Partial discharge measurements

[8] IEC 60282-1: High-voltage fuses – Part: Current-limiting fuses

[9] IEC 60296: Fluids for electrotechnical applications – Unused mineral insulating oils for transformers and switchgear

[10] IEC 60455 (all parts): Resin based reactive compounds used for electrical insulation

[11] IEC 60529: Degrees of protection provided by enclosures (IP code)

[12] IEC 60694: Common specifications for high-voltage switchgear and controlgear standards

[13] IEC 60815: Guide for the selection of insulators in respect of polluted conditions

[14] IEC 61462: Composite hollow insulators – Pressurized and unpressurized insulators for use in electrical equipment with rated voltages greater than 1000V. Definitions, test methods and acceptance criteria and design recommendations

[15] IEC 62271-2: High-voltage switchgear and controlgear – Part 2: Seismic qualification for rated voltages of 72.5 kV and above

[16] CISPR 18-2: Radio interference characteristics of overhead power lines and high-voltage equipment – Part 2: Methods of measurement and procedure for determining limits

[17] IEC 61869-1: Instrument Transformers – Part 1: General

[18] IEC 61869-3: Instrument Transformers – Part 3: Additional requirements for inductive voltage transformers

[19] SANS 121: Hot dip galvanized coatings on fabricated iron and steel articles – Specifications and test method

[20] SANS 2063: Thermal spraying – Metallic and other inorganic coatings – Zinc, aluminium and their alloys

[21] SANS 12944-5: Paints and varnishes – Corrosion protection of steel structures by protective paint systems Part 5: Protective paint systems

Note: Some IEC documents mentioned above are available from SABS with the same number preceded by SANS.

2.2.2 Informative

None

2.3 Definitions

2.3.1 General

Definition	Description
Approved / Approval	Approved in writing by the purchaser.
Arcing distance	Distance in air between two conductive parts.
Burden	admittance (or impedance) of the secondary circuit expressed in siemens (or ohms) and power factor
Creepage Distance	shortest distance, or the sum of the shortest distances, along the insulating parts of the insulator between those parts which normally have the operating voltage between them
Impedance earthed neutral system	A system whose neutral point(s) is(are) earthed through impedances to limit earth fault currents.
Measuring voltage transformer	voltage transformer intended to transmit an information signal to measuring instruments, integrating meters and similar apparatus
Mechanical load (F)	forces on different parts of the instrument transformer as a function of four main forces: • forces on the terminals due to the line connections • forces due to the wind • seismic forces • electro dynamic forces due to short circuit current
Medium voltage	Voltage less than 52 kV, greater than 1 kV.
Nominal voltage of a system (Un)	highest value of the phase-to-phase operating voltage (r.m.s. value) which occurs under normal operating conditions at any time and at any point in the system

Definition	Description
Phase displacement (Δϕ)	difference in phase between the primary voltage or current and the secondary voltage or current phasors, the direction of the phasors being so chosen that the angle is zero for an ideal transformer
Primary terminals	terminals to which the voltage or current to be transformed is applied
Primary winding	winding to which the voltage to be transformed is applied
Protective voltage transformer	voltage transformer intended to transmit an information signal to electrical protective and control devices
Rated burden	value of the burden on which the accuracy requirements of this standard are based
Rated frequency (f_R)	value of the frequency on which the requirements of this standard are based
Rated insulation level	combination of voltage values which characterizes the insulation of a voltage transformer with regard to its capability to withstand dielectric stresses
Rated primary voltage	value of the primary voltage which appears in the designation of the transformer and on which its performance is based
Rated secondary voltage	value of the secondary voltage which appears in the designation of the transformer and on which its performance is based
Rated voltage factor	multiplying factor to be applied to the rated primary voltage to determine the maximum voltage at which a transformer must comply with the relevant thermal requirements for a specified time and with the relevant accuracy requirements
Ratio error (ε)	the error which an instrument transformer introduces into the measurement and which arises from the fact that the actual transformation ratio is not equal to the rated transformation ratio
Secondary terminals	terminals which transmit an information signal to measuring instruments, meters and protective or control devices or similar apparatus
Secondary winding	winding which supplies the voltage circuits of measuring instruments, meters, relays or similar apparatus
Section	electrically conductive part of an instrument transformer insulated from other similar parts and equipped with terminals
Solidly earthed neutral system	A system whose neutral point(s) is(are) earthed directly.
Unified specific creepage distance	creepage distance of an insulator divided by the r.m.s. value of the highest operating voltage across the insulator and is expressed in mm/kV
Valid test certificate	A certified copy of the original test certificate of a test conducted by an approved testing authority.
Voltage transformer	instrument transformer in which the secondary voltage, in normal conditions of use, is substantially proportional to the primary voltage and differs in phase from it by an angle which is approximately zero for an appropriate direction of the connections

2.3.2 Disclosure classification

Controlled disclosure: controlled disclosure to external parties (either enforced by law, or discretionary).

2.4 Abbreviations

Abbreviation	Description
F_R	Rated frequency
HRC fuse	High rupturing capacity fuse
MCB	Miniature circuit breaker
U_m	Highest voltage for equipment
U_n	Nominal voltage
VF	Voltage factor
VT	Voltage transformer / inductive voltage transformer

2.5 Roles and responsibilities

All Eskom employees and/or appointed bodies involved in the procurement of inductive voltage transformers of nominal voltages up to 132kV shall ensure that the product meets the requirements of this standard. Any deviation from these requirements shall constitute a non-conformance, unless if approved in advance by a delegated Eskom instrument transformers specialist in writing and is based on sound engineering judgement.

All the Contractors supplying inductive voltage transformers to Eskom must be conversant with the requirements of this standard, and shall comply with the requirements. All the deviations shall be clearly listed in the deviation schedule as part of the tender deliverables. No deviations will be accepted unless approved by Eskom in writing.

The Eskom Instrument Transformer Care Group is responsible for ensuring that this document is valid at all times.

2.6 Process for monitoring

This document and its relevance will be evaluated by the relevant instrument transformers Care Group.

2.7 Related/supporting documents

Not applicable.

3. General requirements

The schedule A of the relevant A/B schedules shall form part of this standard and they shall take precedence over this standard in case the two documents are conflicting.

3.1 Life expectancy

The life expectancy of inductive voltage transformers under normal service conditions shall be 25 years.

3.2 Standard service conditions

Unless otherwise specified in schedule A, the following standard conditions shall apply:

a) Ambient temperatures:

1) Minimum: -10°C

2) Maximum: 40°C

3) Maximum diurnal variation: 35°C

4) Yearly daily average: 25°C

b) Altitude: Up to 1800m

c) Solar radiation: 2500 kWh/m^2

d) Relative humidity: Not exceeding 95% (measured for a period of 24 hours)

e) Wind Pressure: 700 Pa (corresponding to a 34m/s wind speed)

f) Atmospheric pollution: Very heavy

g) Seismic shock: 0.3g

3.3 System earthing

a) Eskom neutral system is voltage dependent and can either be

1) Solidly earthed neutral system or

2) Impedance earthed neutral system

b) The applicable system earthing shall be specified in the technical schedule.

3.4 Information in technical schedules

a) The following critical information shall be specified in schedule A

1) Single-phase or three-phase application;

2) Indoor or outdoor application;

3) Measurement or protective application (or both);

4) Rated burden and the rated accuracy class for each secondary winding;

5) Nominal system r.m.s. phase-to-phase voltage (Un);

6) Maximum r.m.s. phase-to-phase equipment voltage (Um);

7) Minimum insulation creepage distance;

8) Nominal supply frequency;

9) Method of system earthing;

b) If specified in schedule A, the voltage transformer shall be provided with a power winding that complies with the voltage rating and the continuous current rating.

c) The name of the manufacturer, the type reference of the voltage transformer offered and all other information of the offer shall be stated in schedule B.

4. Ratings

4.1 General

The common ratings of inductive voltage transformers, including their auxiliary equipment if applicable, should be selected from the following:

a) Highest voltage for equipment (U_m);

b) Rated insulation level;

c) Rated frequency (f_R);

d) Rated output and

e) Rated accuracy class

The rating applies at the standardized reference atmosphere (temperature (20°C), pressure (101,3 kPa) and humidity (11 g/m3)) specified in IEC 60071-1.

4.2 Insulation requirements

a) The rated insulation levels for voltage transformers shall comply with the requirements in Table 1.

b) The voltage transformers shall be suitable for operation on a system that has insulation levels as specified in schedule A.

Table 1: Rationalized Voltage Ratings

Equipment Nominal Voltage Rating (U_n) (kV)	Highest Voltage for Equipment (U_m) (kV)	Rated Lightning Impulse Withstand Voltage (kV peak at 1 000 m AMSL)	Rated Power Frequency Withstand Voltage (kV rms at 1 000 m AMSL)
6.6	7.2	75	22
11	12	95	28
22	24	150	50
33	36	200	70
44	52	250	95
66	72,5	350	140
88	100	450	185
132	145	650	275

Note: The rated insulation withstand levels for lightning impulse and short time power frequency withstand are specified in Table 1. The service conditions for South Africa are rationalized for altitudes up to 1 800m. Although the insulation levels in Table 1 are specified at an altitude of 0 m to 1 000 m, the values have been selected for appropriate insulation coordination for altitudes up to 1 800 m and need not be corrected for altitude. The VTs should be supplied with standard values as per Table 1 Test values must, however, be corrected for deviations from the standard reference atmospheric conditions.

4.3 Rated primary terminals insulation level

a) The rated primary terminal insulation level of an inductive voltage transformer shall be based on its highest voltage for equipment U_m according to Table 1.

b) Primary terminal intended to be earthed in service has U_m equal to 0.72 kV.

4.4 Other requirements for primary terminals

4.4.1 Partial discharges

a) Partial discharge requirements are applicable to inductive voltage transformers having $U_m \geq 7.2$kV and the level shall not exceed limits specified in Table 2.

Table 2: Partial discharge test voltages and permissible levels

Type of earthing of the neutral system		PD test voltage (r.m.s.) kV	Maximum permissible PD level PC	
			Liquid or gas insulation	Solid insulation
Earthed Neutral		U_m	10	50
		1.2 U_m /√3	5	20
Non effectively earthed		1.2U_m	10	50
		1.2 U_m /√3	5	20

4.4.2 Chopped impulse

a) Inductive voltage transformers shall be capable to withstand a chopped lighting impulse voltage applied to primary terminals having a peak value of 115% of rated lightning impulse withstand voltage.

4.4.3 Capacitance and dielectric dissipation factor

a) A capacitive test tap is required for dielectric dissipation factor (DDF = tangent-delta) testing and should be brought through a separate terminal (for all inductive voltage transformers having $U_m \geq$ 72kV).

4.4.4 Between-section insulation requirements

a) For interconnected terminals of each section, the rated power-frequency withstand voltage of the insulation between sections shall be 3 kV.

4.4.5 Insulation requirements for secondary terminals

a) The rated power-frequency withstand voltage for secondary terminals insulation shall be 3kV (r.m.s.).

4.4.6 Power-frequency withstand for the earthed terminal

a) The rated power-frequency short-duration withstand voltage shall be 3kV (r.m.s.).

4.5 Rated frequency

a) The rated frequency value is 50Hz.

4.6 Rated output

a) The standard values of rated output used in Eskom at a power factor of 0.8 lagging, expressed in volt-amperes, are 50, 100 and 200 and shall be specified in Technical Schedule A.

4.7 Rated accuracy class

4.7.1 Measuring voltage transformers

a) The accuracy class is designated by the highest permissible percentage voltage error at rated voltage and with rated burden, prescribed for the accuracy class concerned.

b) The standard accuracy class for single-phase inductive measuring voltage transformers used in Eskom is 0.2.

c) The voltage error and phase displacement at rated frequency shall not exceed the values in Table 3 at any voltage between 80% and 120% of rated voltage with rated burden between 25% and 100% at a power factor of 0.8 lagging.

Table 3: Limits of voltage error and phase displacement for measuring voltage transformers

Class	Voltage ratio error ± %	Phase displacement	
		± Minutes	± Centiradians
0.2	0.2	10	0.3

Notes:

1) The errors shall be determined at the terminals of the transformer and shall include the effects of any fuses or resistors as an integral part of the transformer.

2) Where transformers have two separate secondary windings, allowance must be made for the mutual interdependence.

4.7.2 Protective voltage transformers

a) The accuracy class for a protective voltage transformer is designated by the highest permissible percentage voltage error prescribed for the accuracy class concerned, from 5% of rated voltage to a voltage corresponding to the rated voltage factor (1.9). This expression is followed by the letter P.

b) The standard accuracy class for protective voltage transformers used in Eskom is 3P and the same limits of voltage error and phase displacement will normally apply at both 5% of rated voltage and at the voltage corresponding to the rated voltage factor.

c) The voltage error and phase displacement at rated frequency shall not exceed the values in Table 4 at 5% of rated voltage and at rated voltage multiplied by the rated voltage factor (1.9), between 25% and 100% of rated burden at a power factor of 0,8 lagging

Table 4: Limits of voltage error and phase displacement for protective voltage transformers

Class	Voltage ratio error ± %	Phase displacement	
		± Minutes	± Centiradians
3P	3.0	120	3.5

4.7.3 Secondary core accuracy class and marking requirements

a) The standard single-phase outdoor voltage transformers used in Eskom have two secondary windings and their accuracy classes are stated in Table 5.

b) Winding 1 and winding 2 shall be identical, and shall fulfil both protection and measurement accuracy class requirements as indicated in Table 5.

c) One core shall be rated for 100VA or 200VA 3P/0.2, when the other core is not used

Table 5: Accuracy class and terminal marking requirements

Winding Number	1	2
Terminal markings	1a – 1n	2a – 2n
Rated burden / Accuracy class	50VA 3P/0.2	50VA 3P/0.2
	100VA 3P/0.2	Not used
Rated burden / Accuracy class	100VA 3P/0.2	100VA 3P/0.2
	200VA 3P/0.2	Not used

d) Each winding shall fulfil its respective accuracy requirements within its output range (25% to 100% of rated burden), whilst at the same time the other winding has an output of any value from 0% to 100% of the rated burden of that winding.

4.8 Rated voltages

4.8.1 Rated primary voltage

a) The rated primary voltage shall be 1/√3 times rated system voltage (Table 1).

4.8.2 Rated secondary voltage

a) The rated secondary voltage shall be 110V line to line in three-phase system or 110/√3V line to ground.

4.9 Rated voltage factor

a) Phase-ground VTs shall be designed to have a continuous voltage factor of 1.2 and 1.9 for 8 hours.

b) Phase-phase VTs with an isolated-neutral (“floating”), the voltage factor shall be at least 1.2U_m continuous.

4.10 Short Circuit Protection

a) In the case of outdoor VTs, protection against short-circuits shall be provided by 32 A HRC fuses or MCBs in the secondary winding circuits.

b) Short-circuit protection of indoor VTs shall typically be provided by medium-voltage fuses in the primary winding circuits in accordance with IEC 60282-1, and low-voltage fuses in the secondary circuits in accordance with IEC 60269-2. Details of the requirements shall be provided by the Eskom in the technical schedules.

c) The secondary fuses shall be in accordance with fuse system G in IEC 60269-2 (fuse links) with offset base contact, formerly known as the “British Standard clip-in fuse system”. The fuse system has the following requirements:

1) Fuses shall be mounted in the secondary terminal box (see 6.3); and

2) Fuses shall be fitted in the phase conductor and a bolted link shall be fitted in the neutral conductor.

d) The supplier shall state, in schedule B, the calculated primary and secondary short-circuit currents for a short circuit on the secondary terminals, assuming zero source impedance.

4.11 Description of standard inductive voltage transformers used in Eskom

Table 6 summarises the standard inductive voltage transformers used in Eskom

Table 6: Standard VT Options required by Eskom

SAP No.	Voltage Transformer Short Description
402187	VT 1PH 6.6kV/110V 100/50VA 31
243883	VT 1PH 6.6KV/110V 200/100VA 31
402185	VT 1PH 11kV/110V 100/50VA 31
243885	VT 1PH 11KV/110V 200/100VA 31
402179	VT 1PH 22KV/110V 100/50VA 31
243886	VT 1PH 22KV/110V 200/100VA 31
402183	VT 1PH 33kV/110V 100/50VA 31
243887	VT 1PH 33KV/110V 200/100VA 31
402181	VT 1PH 44kV/110V 100/50VA 31

SAP No.	Voltage Transformer Short Description
243888	VT 1PH 44KV/110V 200/100VA 31
180091	VT 1PH 66KV/110V 100/50VA 31
243889	VT 1PH 66KV/110V 200/100VA 31
180090	VT 1PH 88kV/110V 100/50VA 31
243890	VT 1PH 88KV/110V 200/100VA 31
180089	VT 1PH 132kV/110V 100/50VA 31
701222	VT 1PH 132KV/110V 200/100VA 31

Note: There are inductive voltage transformers used in Eskom which are regarded as non-standard due to low utilisation, when they are require, their special requirements shall be stated in technical schedule A.

5. Design and construction

5.1 Requirements for liquids used in equipment

5.1.1 General

a) The manufacturer shall specify the type and the required quantity and quality of the liquid to be used in the equipment in schedule B.

b) Facilities for oil filling and draining shall be provided. These facilities shall be suitably sealed below the normal operating oil level and shall not leak oil when the transformer is tested.

c) The method used to allow for the expansion of the insulating oil shall be submitted for approval. If bellows are used, they shall be of stainless steel.

d) If so specified in schedule A, oil sample valves shall be provided. Details of the oil sample valves shall be submitted for approval before manufacturing is undertaken.

5.1.2 Liquid quality

a) For oil-filled equipment, insulating oil shall comply with IEC 60296.

b) The oil shall be virgin, naphthenic based and shall have no additives.

c) The oil shall be certified to contain no polychlorinated biphenyls (PCB), i.e. a zero count.

5.1.3 Liquid level device

a) The device for checking the liquid level shall indicate whether the liquid level is within the operating range, during operation.

b) Oil-level indicators shall be provided and shall be so designed and positioned as to be readable from ground level, with the voltage transformer mounted on its structure as in service. Details of the oil-level indicators shall be submitted for approval.

c) Oil-level indicators shall be flush mounted and shall be securely attached along their perimeter to the tank or expansion chamber.

d) The sight glass shall be resistant to ultraviolet radiation and shall be protected from accidental damage during transport, installation or maintenance.

5.1.4 Liquid tightness

a) No liquid loss is permitted (i.e. inductive voltage transformers shall be hermetically sealed). Any liquid loss represents a danger of insulation contamination.

b) Details of the sealing arrangement shall be submitted for approval if requested in schedule A.

c) All gasketted joints shall be below the minimum oil level, and shall not leak oil when the transformer is tested. In addition, the design and materials shall be suitable for normal operating service conditions for the duration of the expected service life of approximately 25 years.

d) Where the manufacturer's design requires specially designed gasketted joints to be above the oil level, machined surfaces and O-rings shall be used. Details of such joints shall be submitted for approval if requested in schedule A.

5.2 Requirements for solid materials used in equipment

a) Dry type VTs shall have resin-encapsulated windings and shall be limited to medium voltage.

b) Specifications for organic material used for instrument transformers (i.e. epoxy resin, polyurethane resin, epoxy-cycloaliphatic resin, composite material, etc.) either for indoor or outdoor installations are given in the IEC 60455 series.

c) Dry type CTs shall have resin-encapsulated cores and windings.

5.3 Requirements for temperature rise

5.3.1 General

a) The temperature-rise of a voltage transformer at the specified voltage, at rated frequency and at rated burden, or at the highest rated burden if there are several rated burdens, at any power factor between 0,8 lagging and unity, shall not exceed the appropriate values given in Table 7, when operating under service conditions specified in paragraph 3.2.

b) The temperature rise of the windings is limited by the lowest class of insulation either of the winding itself or of the surrounding medium in which it is embedded.

c) If the instrument transformers are used within enclosures, attention shall be paid to the temperature reached by the surrounding cooling media within the enclosure.

d) When the transformer is fitted with a conservator tank or has an inert gas above the oil, or is hermetically sealed the temperature rise of the oil at the top of the tank or housing shall not exceed 55K.

Table 7: limits for temperature rise

Part of voltage transformer	Temperature rise limit K
1. Oil immersed voltage transformers	
• Top oil	50
• Top oil hermetically sealed	55
• Winding average	60
• Winding average, hermetically sealed	65
• Other metallic parts in contact with oil	As for winding
2. Solid insulated voltage transformers	
- Winding (average) in contact with the following insulating material	
• Y	45
• A	60
• E	75
• B	85
• F	110
• H	135
• Other metallic parts in contact	As for windings

5.3.2 Influence of altitude on temperature

If an inductive voltage transformer is specified for service at an altitude in excess of 1 000m and tested at an altitude below 1 000m, the limits of temperature rise ΔT given in Table 7 shall be reduced by the following amounts for each 100m that the altitude at the operating site exceeds 1 000 m:

a) Oil-immersed inductive voltage transformers: 0.4% and

b) Dry-type inductive voltage transformers: 0.5%.

5.4 Requirements for earthing

a) The frame of inductive voltage transformers shall be provided with an earthing terminal for connection to an earthing conductor suitable for specified fault condition.

b) The connecting point shall be marked with the “earth symbol”, as indicated by symbol No 5019 of IEC 60417.

5.5 Requirements for external insulation

a) For outdoor inductive voltage transformers with ceramic (porcelain) or composite insulators susceptible to contamination, the creepage distance of 31mm/kV (very heavy pollution level) shall be used.

b) For the compilation of schedule A, the required total creepage distance, in millimetres, should be calculated.

c) For voltage levels up to and including 145 kV, a specific creepage distance (SCD) of 31 mm/kV in relation to the highest r.m.s. phase-to-phase voltage (U_m) should be calculated.

Notes:

1) Ratio of the creepage distance between phase and earth over the r.m.s. phase-to-phase value of the highest voltage for the equipment (see IEC 60071-1).

2) For further information and manufacturing tolerances on the creepage distance, see IEC 60815.

5.6 Mechanical requirements

a) The requirements apply to inductive voltage transformers rated for highest voltage of 72.5kV and above. Inductive voltage transformers must be able to withstand static loads given in Table 8 applied in any direction to the primary terminals.

Table 8: Static withstand test loads

Highest Voltage for Equipment Um kV	Static withstand test load FR N	
	Load Class 1	Load Class 2
72.5 - 100	1250	2500
123 - 170	2000	3000

5.7 Internal arc fault protection

a) The requirements apply to oil immersed freed-standing inductive voltage transformers with $U_m \geq$ 72.5kV for which arc fault protection is additionally specified.

b) If the requirements are specified, an inductive voltage transformer must be able to withstand internal arc of the specified current and duration specified in Table 9.

Table 9: Arc fault duration and protection criteria

Internal arc fault current r.m.s. value kA	Protection stage	Arc fault duration s	Internal arc fault protection class I	Internal arc fault protection class II
<40	1	0.2	Fracture of housing and fire permitted, but all projected part to be within the containment area	No external effect other than the operation of pressure relief device
	2	0.5		No fragmentation (burn-through or fire acceptable)
≥40	1	0.1		No external effect other than the operation of pressure relief device
	2	0.3		No fragmentation (burn-through or fire acceptable)

NB: This test is not a guarantee against containment under all short-circuit conditions, but a test to demonstrate conformance to an agreed level of safety.

c) If required in schedule A, the inductive voltage transformer construction shall comply with the fail-safe design, yielding a low explosion risk. The supplier is to provide details of the fail-safe design features in the tender.

5.8 Degrees of protection by enclosures

a) The recommended minimum degree of protection for low-voltage control and/or auxiliary enclosures for outdoor voltage transformers is IP56.

5.9 Electromagnetic compatibility

5.9.1 Requirement for Radio Interference Voltage (RIV)

a) The requirement applies inductive voltage transformers having $U_m \geq 123$kV to be installed in air-insulated substations. The radio interference voltage shall not exceed 2 500µV at $1.1U_m/\sqrt{3}$.

5.9.2 Requirement for transmitted overvoltages

a) These requirements apply to inductive voltage transformers having $U_m \geq 72.5$ kV. The overvoltages transmitted from the primary to the secondary terminals shall not exceed the values given in Table 10.

Table 10: Transmitted overvoltage limits

Type of impulse	Air insulated voltage transformers
Peak value of applied voltage (U_p)	$1.6 * \frac{\sqrt{2}}{\sqrt{3}} * U_m$
Waveshape characteristics • conventional front time (T_1) • time to half (T_2)	 0.5µs ± 20% ≥ 50µs
Transmitted overvoltage peak limits (U_s)	1.6kV

6. Construction

6.1 Primary terminals

a) Primary terminals shall be of the type and orientation specified in technical schedule A.

b) Where stems are specified, these shall have a terminal length of 125mm and a diameter of 26mm.

c) Primary terminals and associated parts shall be of an approved material of adequate conductivity and shall be suitably protected against corrosion. Non-ferrous terminals shall be electro-tinned to comply with, classification Cu/Sn/12/f in BS 1872 without subsequent heat treatment or machining.

d) Primary terminals and their associated parts, mounted on inductive voltage transformers as in service, shall be able to withstand the mechanical tests without leakage, distortion, cracking or other failure.

e) The design factor of safety shall be not less than 2.

6.2 Secondary terminals

a) The bushings used for bringing the secondary connections through the tank into the secondary terminal box shall not be used as the secondary terminals for service connections, unless approved by Eskom.

b) Studs shall have centre distances of not less than 25mm. A minimum clearance of 12mm shall be maintained between terminals. Stud terminals shall be size M6.

c) The secondary terminals shall be rail-mounted, and shall be the spring-loaded screw clamp type of 10 mm width in accordance with IEC 60947-7-1. The terminals shall accept two back-to-back hook blade lugs.

6.3 Secondary terminal boxes

a) Each VT shall be fitted with a secondary terminal box that shall be located in an accessible position and shall be provided with an easily removable (preferably slip-on) weather-proof cover. When in place, the cover shall be secured to the corresponding terminal box by means of a minimum M8 stainless steel set screw or an otherwise approved method.

b) The type of terminal box shall be stated in schedule B and, subject to approval, shall be either:

1) Integrally cast with the VT case; or

2) Steel box welded to the main tank.

c) The terminal box with the cover fixed in place shall have a degree of protection of at least IP56 in accordance with IEC 60529.

d) The secondary terminal box shall have an opening, at the bottom of the box, for vertical entry of the secondary control cables. The opening shall be covered externally by an undrilled, removable gland plate of brass (of minimum thickness 2mm), aluminium alloy (of minimum thickness 3mm) or stainless steel (of minimum thickness 2mm). Unless otherwise specified in schedule A, this gland plate and the opening shall have an effective area of at least 75mm × 50mm. This area shall be stated in schedule B. Access to the gland-plate opening shall not be obstructed for cables that enter the terminal box vertically from below.

e) The distance between the bottom terminals and the gland plate shall be at least 75 mm.

f) The terminal box shall be fitted with a breathing vent of diameter at least 10 mm. This vent shall be situated in the bottom of the box, shall be made of non-corroding material and shall be designed to prevent the entry of insects.

g) The beginning and the end of each secondary winding shall be wired to suitable terminals accommodated in the terminal box.

h) An earth stud shall be provided for earthing of the primary winding neutral and secondary windings inside the terminal box. The earth stud shall be of diameter at least 6 mm and shall be welded to the terminal box.

i) Where required in the technical schedule, a capacitive tap connection shall be connected to an insulated terminal inside the terminal box. This terminal shall be clearly labelled and display a warning that it shall be solidly earthed during service.

6.4 Tanks

a) The tank shall have an unpainted earthing flag of 5 mm × 50 mm × 100 mm (minimum), with two 14 mm holes at 50 mm centres arranged vertically. The flag shall be situated in close proximity to a tank mounting bolt hole on the same side as the terminal box.

b) Alternative designs shall be submitted for approval, and, in the case of painted tanks, the underside of transformer tank mounting flanges shall be zinc metal sprayed, and shall not be painted.

c) Corrugated tanks are not acceptable. Tanks and fittings shall be of such shape that water cannot collect at any point on the outside surfaces.

6.5 Hollow core insulators

a) Insulators shall comply with IEC 60815-2 and IEC 61462.

b) The name of the manufacturer and the country of origin of the HV insulators shall be stated in schedule B, and detailed drawings of the insulator shall be supplied with the tender. Permission shall be obtained from the purchaser before a change of insulator supplier during the course of a contract.

6.6 Mounting arrangement for outdoor VTs

a) The base mounting arrangement for the VTs shall be such that it can be bolted to a support structure, with mounting holes arranged on the corners of a square of dimensions not exceeding those specified in schedule A.

6.7 Corrosion

a) Corrosion protection shall be in accordance with [1].

b) Unless otherwise approved, all ferrous parts associated with voltage transformers shall either be:

1) Hot-dip galvanized in accordance with SANS 121, of minimum coating thickness not less than 90µm; or

2) Zinc metal sprayed in accordance with SANS 2063, of minimum coating thickness not less than 80µm.

c) Metallization shall be followed by a base coat and top coat in accordance with SANS 12944-5. Metallization shall be followed by a base coat and top coat in accordance with SANS 12944-5.

d) All materials shall be inherently corrosion-resistant or treated against corrosion for the design lifetime of the equipment.

6.8 Markings

6.8.1 Terminal Markings

6.8.1.1 General rules

a) These markings are applicable to single-phase voltage transformers.

b) Capital letters A, B, C and N denote the primary-winding terminals and the lower-case letters a, b, c and n denote the corresponding secondary-winding terminals.

c) The letters A, B and C denote fully insulated terminals and the letter N denotes a terminal intended to be earthed and the insulation of which is less than that of the other terminal(s).

d) Terminals having corresponding capital and lower-case markings shall have the same polarity at the same instant.

NB: Further clarity on terminal markings is provided in Paragraph 6.13 of IEC61869-3.

6.9 Rating and diagram plates

a) The plates shall be manufactured from anodized aluminium or stainless steel.

b) The material and the method of mounting the plates shall be stated in schedule B.

c) Rating plates and diagram plates shall be engraved or have the information stamped into an intrinsically corrosion-resistant material, and shall be externally mounted.

d) Rating plates and diagram plates shall be mechanically fixed e.g. screwed or riveted to the main body of the voltage transformer and not to any removable part. NB: mounting by means of adhesives is not acceptable.

e) The rating plates and diagram plates shall be so positioned that they may easily be read by personnel without their lives being endangered.

f) The size of the characters shall be not less than 4 mm.

g) The following information shall be engraved or stamped into the rating plate:

1) Manufacturer's name;
2) Year of manufacture, serial number and type designation;
3) Rated frequency;
4) Rated primary and secondary voltage;
5) the rating of the fuse(s), as applicable;
6) Rated output and corresponding accuracy class;
7) Rated voltage factor and corresponding rated time;
8) Highest voltage of equipment;
9) Rated insulation level;
10) the volume of oil, in litres, for oil-filled VTs;
11) Mass in kg and
12) Class of mechanical requirements (for $U_m \geq 72kV$);

NB: Some items can be combined e.g. 24/50/150kV

6.10 Warranty

Eskom only accepts inductive voltage transformers with a minimum warranty of 5 years.

7. Tests

7.1 General

7.1.1 Classification of tests

The tests specified in this standard are classified as follows:

a) Type test: a test made on equipment to demonstrate that all equipment made to the same specification complies with the requirements not covered by routine tests.

b) Routine test: a test to which each individual piece of equipment is subjected. Routine tests are for the purpose of revealing manufacturing defects. They do not impair the properties and reliability of the test object.

c) Special test: a test other than a type test or a routine test, agreed on by manufacturer and Eskom.

7.2 Type tests

Unless valid and approved type test certificates specified in IEC 61869-1, IEC 61869-2 and in schedule A are available, type tests must be carried out on one fully assembled voltage transformer of each type and rating at an IEC approved test facility. The certificates of the tests shall be included in the test reports. Type tests shall be followed by routine tests. Type tests are listed in (a) to (h):

a) Temperature rise test

b) Lightning impulse test on primary terminals

c) Wet test for outdoor type transformers

d) Electromagnetic Compatibility Tests (Radio interference voltage for inductive voltage transformers with $U_m \geq 123kV$)

e) Test for accuracy

f) Verification of the degree of protection by enclosures

g) Pressure test for the enclosure

h) Short-circuit withstand capability test

7.3 Routine tests

7.3.1 General

Each fully assembled voltage transformer shall be subjected to the routine tests mentioned below at the manufacturer's works to prove compliance to this standard.

a) Power-frequency withstand test on primary winding

b) Partial discharge measurement

c) Power-frequency withstand test on secondary terminals

d) Power-frequency withstand tests between sections

e) Test for accuracy

f) Verification of terminal markings

g) Measurement of capacitance and dielectric dissipation factor (tan delta) tests

7.3.2 Capacitance and dielectric dissipation factor (tan delta) tests

7.3.2.1 General

a) The main purpose is to check the uniformity of the production. Conduct this test after the power-frequency withstand test; this test is applicable to all oil-immersed paper-insulated inductive voltage transformers with $U_m \geq 72.5$ kV. Record the tangent delta and the capacitance (C) readings at 10 kV on the information plate mounted on the tank for the purposes of condition monitoring.

b) Raise the voltage applied between primary terminal and the earth screen terminal to 120% of $U_m/\sqrt{3}$. While the voltage is being raised, record the tangent delta measurements at voltages of 10kV, 66.6%, 100%, and 120% of $U_m/\sqrt{3}$. Thereafter, take the measurements in the reverse order back to 10kV, i.e. 100%, 66.6% and 10kV.

c) The voltage transformer is deemed to have passed the test when it meets the following two conditions:

1) The absolute value of tangent delta readings at each step, during both excursions, is not more than 0.5% (i.e. 0.005) and

2) The difference in percentage value between the reading at the maximum test voltage (120% of Um/√3) and the reading at the minimum test voltage (10 kV) is not more than 0.0015.

7.4 Special tests

When specified in schedule A, special tests shall be performed and may be specified as type tests. The following special tests which are listed and described in detail in IEC 61869-1 and IEC 61869-2 are required by Eskom:

a) Chopped impulse voltage withstand test on primary windings

b) Mechanical tests (applicable to inductive voltage transformers with $U_m \geq 72.5kV$)

c) Transmitted overvoltage test (applicable to inductive voltage transformers with $U_m \geq 72.5kV$)

d) Internal arc fault test (applicable to inductive voltage transformers with $U_m \geq 72.5kV$)

e) Corrosion test

7.4.1 Mechanical tests

When the mechanical tests on primary terminals are specified in schedule A, the applied design factor of safety shall be at least 2.

7.5 Test certificates (Routine tests certificates)

a) Each VT shall be delivered with one copy of all routine test certificates.

b) These certificates and curves shall be packed in a waterproof container and housed inside the terminal box of each respective voltage transformer.

c) All tests shall be fully documented in English, signed by the relevant (competent) manufacturer's personnel and stamped.

d) Electronic copies must be stored by the manufacturer for a period not less than 10 years and be made available to Eskom upon request.

7.6 Works inspections and witnessing of tests

a) Eskom reserves the right to appoint a representative to inspect the inductive voltage transformers at any stage of manufacture, or to be present at any of the tests specified.

8. Marking, labelling and packaging

a) The marking, labelling and packaging details are to be submitted to Eskom for approval prior to manufacturing.

b) Imported VTs shall be packaged in robust wooden crates and suitably supported in order to protect the VT from the stresses of normal handling that can be expected from the point of despatch to the point of construction.

c) Crates must be designed such that inspection can be effected without opening or damaging the crate. The crate must be able to be lifted by slings with lifting points clearly marked. Any special handling requirements shall be clearly specified to purchaser before delivery and shall be clearly specified on packaging.

d) Packaging shall not disintegrate due to exposure to rain and direct sunlight during outdoor storage and the construction period of 18 months in total. The manufacturer/supplier shall notify the purchaser of any special methods recommended for storage prior to delivery, and on packaging materials.

e) If VTs are packed in crates on pallets, the gross weight of the pallets shall not exceed 1 800 kg. Pallets shall be suitable for handling by forklift trucks, capable of entry from both sides. All boxes, pallets or containers shall be clearly marked in accordance with the following example, or similar approved template:

1) Eskom Order No.:
2) Eskom SAP No.:
3) Project Name:
4) Project Number:
5) Delivery Address:
6) Supplier's Name:
7) Supplier's Serial No.
8) Technical Description of voltage transformers
9) Gross Weight:

8.1 User manual

a) The manufacturer must provide Eskom with an electronic user manual in pdf format specifying the following details:

1) Packaging,
2) Handling (correct handling and slinging methods),
3) Transportation,
4) Installation,
5) Storage (short and long terms) and
6) Maintenance

9. Documentation

9.1 Tender documentation

a) The following technical information and drawings shall be submitted as part of the tender:

1) Completed technical schedule,
2) Technical deviation sheet (in case there are deviations)
3) Voltage transformer outline drawing,
4) Detailed drawing of the insulator
5) Instruction / user manual
6) Type test reports

b) Unless otherwise specified in schedule A, one hard copy and one digital copy of all documentation pertaining to the equipment offered shall be supplied. The digital copy shall be shall be compatible with "Adobe Acrobat pdf" format. All information shall be in English.

9.2 Contract documentation after tender award

a) The following drawings and technical information shall be submitted for final approval after the contract is awarded but before manufacturing can commence:

1) Outline drawing
2) Section drawing
3) Terminal box drawing (internal part)
4) Detailed drawing of the rating plate
5) Scheme diagram
6) Instruction / user manual
7) Typical routine test sheet

10. Drawings

10.1 Details of drawings

10.1.1 Outline drawing

a) An outline drawing that shows the following minimum information shall be provided for each type of VT such that the physical arrangement can be correlated with the electrical schematic arrangement:

1) Short technical description in the title block (e.g. Outline VT 1PH 132kV/110V 100/50VA 31)
2) The type of insulating material,
3) Mounting details,

a) Primary terminal dimensions and markings,

b) Overall dimensions,

c) The position of the earthing terminal,

d) The height of the gland plate in the secondary terminal box above the base, and the distance of the terminal box centre-line from the centre-line of the VT,

e) The total creepage and the arcing distance of the hollow core insulator; and

f) The mass of the complete VT and the volume of the oil

g) Allowance for the inclusion of:

1) Eskom SAP number; and
2) Eskom drawing number

Note: The numbers shall be incorporated in the drawing upon issue.

10.1.2 Section drawing

a) A sectional arrangement drawing, which depicts the following details, shall be supplied:

1) The relative position of the core and windings,
2) The hollow core insulator,
3) Oil-sealing arrangement,
4) The method used to accommodate expansion of the oil and
5) Pressure-relief device, where applicable

10.1.3 Insulator drawing

a) A detailed drawing of the insulator showing all important dimensions shall be provided.

10.1.4 Terminal box

a) A detailed drawing of the terminal box showing the following:

1) Method of affixing the cover,
2) Position and dimensions of the gland plate
3) Arrangement and clearances of the secondary terminals, creepage extension barriers, if applicable, and markings; and
4) Breathing arrangement

11. Authorization

This document has been seen and accepted by:

Name and surname	Designation
Sibongile Maphosa	Engineer (TX AME – Substation Equipment & Diagnostics)
Bheki Ntshangase	Senior Manager (TX AME – Substation Equipment & Diagnostics)

12. Revisions

Date	Rev	Compiler	Remarks
Nov 2021	2	S Maphosa	Changed the content from being Eskom requirements only to being a fully-fledged standard
July 2014	1	M Sekgobela Hans Boshoff	Final Document approved on SCOT template. No content change from 34-1688.

13. Development team

The following people were involved in the development of this document:

- Sibongile Maphosa

14. Acknowledgements

The development team would like to acknowledge all members of the Instrument Transformers Care Group who contributed to this standard.